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Introduction.

This paper is a discussion of a part of the mineral wealth of the States of Oaxaca and Puebla, Mexico. It does not refer to the precious metals, some mines of which, in these States, are said to have been worked before the advent of the Spanish *conquistadores* in the sixteenth century, as my purpose is to invite attention to the exploration of deposits of coal and iron-ores in the Mixteca region. The prominence given to coal is warranted by the great effect of the scarcity of fuel upon the industrial development of Mexico. Under the progressive administration of President Porfirio Diaz, the Republic has made wonderful advances in the past three decades; and this progress would have been greater but for the limitations imposed by expensive fuel.

In the spring of 1906 I was detailed by the Birkinbine Engineering Offices, of Philadelphia, to accompany A. B. Adams, of New York, in a reconnoissance of reported deposits of iron-ores in the State of Oaxaca. The result of this expedition was the formation, in 1907, of the Oaxaca Iron & Coal Co., of which Mr. Adams became, and has remained, President and General Manager, and I have spent the past three years as Chief Engineer of this company in Mexico, principally in western Oaxaca, where field-headquarters were established.

Geography and Population.

Although the geographical and topographical features of the Republic of Mexico are well known, few realize that the majority of its population is domiciled in the States which immediately surround the capital city of Mexico, including the Federal District, Mexico, Tlaxcala, Morelos, Puebla,

Oaxaca, Vera Cruz, Hidalgo, San Luis Potosi, Queretaro, Guanajuato, Aguascalientes, Jalisco, Colima, and Michoacan. These States cover 177,600 sq. miles of the national total of 767,300 sq. miles. The census of 1900 gave these 15 States a population of more than 9,485,000, out of 13,606,000 for the entire Republic. In other words, 23 per cent. of the area of the Republic contains 70 per cent. of its population. With the possible exception of the portion of the State of Vera Cruz adjacent to Gulf ports, the present price of coal in this region ranges from $7 to $15 a ton, on board cars at railroad termini. (The values are given in gold. Mexican currency is taken as worth 50 per cent. of gold-value.) Within the region numerous mining and industrial centers are seeking economical power; and coal, crude oils, and gas (utilized in gas-engines), as well as hydro-electric installations, have received attention and encouragement. Mexico City being the center of population, industry, and commerce in the Republic, the prices of various commodities at that place are given in this paper. The metric ton of 2,204.6 lb. av. is used, unless some other unit is stated.

Fuel in Mexico.

Wood and charcoal, exclusively used as fuel in the past, are still largely relied upon, even in important cities; but the rapid destruction of forests adjacent to lines of transportation has greatly augmented the cost of vegetable fuel throughout the Republic, thus encouraging the use of coal, which is now generally burned under boilers, and has been utilized lately in gas-producers, the gas thus generated being supplied to heating-furnaces and to internal-combustion motors for power. Some industries are applying waste charcoal-breeze in special producers to operate gas-engines; and numerous locomotives are burning crude native petroleum.

The most densely populated part of Mexico is distant from present fuel-supplies. The wood along the railroads entering the valley of Mexico has been depleted; and the only domestic coal now available is mined more than 800 miles to the north; while foreign coal must be transported from Gulf ports, a distance of 264 miles by minimum haul, overcoming an elevation of 8,400 ft. before descending into the valley of Mexico, the altitude of which is 7,300 ft., and necessitating a charge of

John Birkinbine

$4.75 per ton for freight between Vera Cruz and Mexico. Foreign coal, therefore, costs from $10 to $11 per ton in Mexico City, and about 25 cents less in Puebla. Anthracite coal from the United States and "Crown fuel"-briquettes, imported from Great Britain, command from 50 cents to $1 per ton more than bituminous coal.

In the northern part of Coahuila, extensive coal-deposits have been developed, but they are more than 800 miles from the City of Mexico, and 6,000 ft. below it in altitude; and the railroad freight-charge averages about $4.50 per ton, making the domestic coal sell in Mexico City at from $8.50 to $10 per ton. The Coahuila coal is high in ash (from 15 to 18 per cent. by average analyses of imperfectly-washed coal); indeed, coal from this field carrying as much as 25 per cent. of ash has been sold in Mexico City. These deposits were described by Edwin Ludlow in a paper presented at the Institute meeting in Mexico, November, 1901.[1]

Coal has been found also in the State of Sonora, still further from Mexico City. These deposits were described by Prof. E. T. Dumble[2] before the Institute in 1899.

Petroleum, which is obtained along the Gulf coast, commands about the same price per ton as Crown fuel-briquettes or Pennsylvania anthracite, being handicapped by the same transportation-charges to Mexico City. Lately the wells have been damaged by the intrusion of salt water, which, while not interfering with the character of the refined products, affects the value of crude oil as fuel, and thus restricts consumption, especially on the railroads.

The Mixteca Region.

Near the central portion of the Republic, between the parallels of latitude 15° and 18° 30′ north, and between the meridians of longitude 20° to 21° 15′ west of Washington, is the Mixteca region, embracing about the western third of the State of Oaxaca and the southwestern portion of the State of

[1] The Coal-Fields of Las Esperanzas, Coahuila, Mexico, *Trans.*, xxxii., 140 to 156 (1902).

[2] Notes on the Geology of Sonora, Mexico, *Trans.*, xxix., 122 to 152; and Natural Coke of the Santa Clara Coal-Field, Sonora, Mexico, *Trans.*, xxix., 546 to 549 (1899).

FIG. 1.—MAP OF THE MIXTECA COUNTRY, STATES OF OAXACA AND PUEBLA, MEXICO, SHOWING COAL-BASINS, IRON-ORE DEPOSITS, AND EXISTING AND PROPOSED RAILROADS.

Puebla. The country is mountainous, extending from sea-level at the Pacific ocean to 10,000 ft. above, the average altitude being more than 5,000 feet.

Its ancient history, like that of many other parts of Mexico, is unknown; but numerous ruins and peculiar languages or customs, which still prevail, indicate that the original Mixtecas had reached a comparatively high plane of civilization. According to common legend, supported by the opinion of some archæologists who have lately visited this portion of Mexico, the Mixteca Indians antedate the Aztecs, and it is possible that they accompanied the Toltecs when these entered Mexico from the north. In some parts of Oaxaca there are colonies of Indians known as "*triques*," believed to have been originally communities of prisoners gathered from the numerous campaigns of the Mixtecas against other tribes. What can be learned of the history of the Mixtecas indicates that they retained their independence until after the arrival of the Spaniards in 1525; and it is commonly asserted that the Mixtecas and the Tlaxcalans were the only two independent tribes that withstood the conquest of the war-like Aztecs, to whom even their former allies, the Zapotecas, were finally forced to yield.

The Mixteca region is divided topographically into two parts, known as the Mixteca Arriba and the Mixteca Baja; and inhabited by separate clans, exhibiting still marked differences in language.

The Mixteca Indian is usually peaceful and industrious, and develops, with very little training, into a skilled workman with a tendency to be busy before the working-day begins and to continue long after hours in order to complete the task once begun. He has a happy disposition and works for very small wages, so long as he may remain in his own part of the country, to which he is strongly attached. Although always craving for an opportunity to visit Mexico City, he is just as anxious to return to his own land, as soon as he has seen some of the modern wonders of the capital.

In our reconnoissances in the spring of 1906, we were probably the first American party to make an extended visit to this part of Mexico. For weeks at a time we traveled on horseback through this unmapped portion of the Republic with perfect security, receiving everywhere not only courtesy but

sincere hospitality. Doubtless many of the attentions we received were due to letters and instructions sent by General Diaz (who, like the other great executive of Mexico, Benito Juarez, was a Oaxacan), and by the present Governor of the State, Emilio Pimentel. Yet, even *peones*, who had no way of knowing that we were bearers of official letters, were spontaneous in their courtesy and assistance, showing their desire to aid us in every way. In three years of nearly continuous residence among these people, I have found them always courteous, reliable, and honest. So much has been published concerning the indolence, inefficiency, and dishonesty of the Mexican *peon*, that the above statement, based upon long and intimate association, is offered as an offset to the generally-accepted opinion.

Labor.

The Mixteca Indians furnish an ample supply of labor, and, with little training, become skilled in the duties assigned to them. The following rates of wages prevail throughout the work:

Day-laborers, unskilled, and speaking only the Mixteca dialects, receive from 9 to 12.5 cents per day of from 10 to 12 hours.

Day-laborers, unskilled, but speaking Spanish, and also mine-muckers, receive 12.5 to 18 cents per day.

Gang-foremen, blacksmiths, and carpenters, 31 cents per day.

General foremen and special office- and laboratory-man, 50 cents a day.

They appear to be born mechanics, soon learning to fire the drill-boilers, to operate the hoisting-engine, and to make, out of old pieces of available scrap, any small parts necessary for repairs. They can be trusted, if not too severely tempted, and, if treated with kindness and firmness, they are extremely loyal. For packing heavy loads they are invaluable and indefatigable. Like all other Spanish-American countries, Mexico has innumerable feast-days; but hitherto our men have been perfectly willing, in cases of necessity, to let these go by. Their chief weakness is a love for alcoholic drinks, especially *aguardiente* (which is practically pure alcohol); and their favorite time for its consumption is on Sundays and holidays.

Surveys.

The exploratory concession granted to the company embraced nearly 11,000 sq. miles, the existing cartography of which was either meager or inaccurate. It was therefore necessary to survey this area. There is a government triangulation-system (known as the triangulation upon the meridian 98° west of Greenwich) embracing much of this region. The stations are from 20 to 70 miles apart, and we were consequently obliged to make a secondary triangulation at essential points. Two base-lines were measured, one in the vicinity of Tlaxiaco, 1,691.785 m., and the other, 1,126.12 m. long, in the vicinity of Tezoatlan. The first, or Tlaxiaco, system of triangulation embraced an area of 360 sq. km. (more than 140 sq. miles), with several high peaks at greater distances (located by observations from two points). One of the government triangulation-stations formed part of this system. The Tezoatlan system included 600 sq. km. (more than 230 sq. miles). From the secondary triangulation-stations, third systems were extended to cover smaller areas, embracing the coal-fields at Mixtepec and at Mina Consuelo. In the vicinity of Mina Consuelo and of Tlaxiaco, the meridian was determined, and permanent monuments were erected.

It may be of interest to detail the method of obtaining base-line measurements, in a country where a satisfactory straight line on ground, which was level or had a uniform slope, could not be secured, and the system carried out in the triangulation. The base-line was determined with a standardized steel-tape, 100 m. long, supported at intervals of 5 m., measurements being taken when the temperatures of the ground and of the air were practically uniform, with a strain of 15 lb. on the tape. The supporting-stakes were on uniform grade-lines, and each end of a grade-line was considered as an intermediate station. The difference in elevation between these ends of grade-lines was subsequently determined by means of a level. Two sets of measurements with the tape and two sets of levels were run over the base-line by different observers, and the results were calculated. When these checked within 5 mm. the mean was adopted as the final measurement. From the ends of the base-line the triangulation was made with a Gurley light mountain-transit, graded to read to 30″, the angles being repeated 10

times, and the total being divided by 10 gave the reading within 3″. Where any angle or measurement of a series differed from the mean by 30″ or more, a new series of readings was taken. The light mountain-transit was adopted, although having the disadvantage of a small limb, because its ease of transportation and stability in adjustment made it superior to the larger transits for the use to which it was put. All transits were equipped with full vertical circles and two with Segmuller solar attachments for determining the meridian at distant points by observations on the sun; also one with a repeating vertical arc, in order that leveling by vertical angles and determination of latitudes could be accurately made.

In addition to the above-mentioned triangulation-systems, 400 acres have been covered by accurate topographic survey, and sketch-topography covering 1,250 sq. miles has been made. Most of this work has been done by Assistant Engineer H. N. Roberts, who deserves credit for accuracy, thoroughness, and close attention to details. Practically all the concession of 11,000 sq. miles, as well as several thousand square miles in the State of Puebla, has also been reconnoitered on horse-back or on foot.

Equipment.

As it required from 3 to 5 days for mail to pass from the headquarters at Tlaxiaco, and from 5 to 7 days from the field-headquarters of Mina Consuelo, to Mexico City, while freight and express consumed from 10 to 30 days in transit, it was necessary to equip the corps liberally, including a miniature field drug-store for accidents or sickness (which, fortunately, has been little used in the past three years). Drawing-rooms were established at the two above-mentioned points for plotting maps and geological data, the designing of head-frames and small ventilation-systems for some of the drifts, etc. A field-laboratory, first established at Tlaxiaco, but later moved to Mina Consuelo, was equipped to make chemical analyses of iron-ores and coals, and provided with apparatus for certain physical tests, including a Parr calorimeter and a petrographical microscope. Several crude pieces of apparatus were constructed for experimental tests in sizing or washing coal. Two "C" Sullivan diamond-drills, with water-tube boilers, pumps, drill-rods, core-barrels, casing, stand-pipe, and necessary tools

and extra parts, were transported to the field-headquarters by mules. Hand-drills, sledges, tools, blacksmith and carpenter outfits, portable forges, provisions, and camp-equipment were also provided. At Mina Consuelo it was necessary to erect all buildings, which at first were of the native style, bamboo tied with *reatas* (*i. e.*, ropes made from palm-leaves) and a roof made from the palm; but these were afterwards superseded by a log-cabin, in which the logs were held together by pins of wood, with split-shingle roof. Dwelling-houses, laboratory, and dining-room were built of logs and split shingles, as well as the head-frame at the shaft, store-house, stable, and blacksmith-shop.

Since the only hand-tools available in the field of our explorations were of ancient design (with which, however, the natives did excellent but slow work), the equipment supplied included what would be a fair stock for a small hardware-store in the United States.

Our assistants came from the United States, England, and Canada, but the packing and other labor was done by a liberal force of natives, whose wages, however, did not make the work expensive.

The reconnoitering parties were equipped with horses, saddles, *serapes* (native blankets), and *ponchos* for each member; and each party had also an aneroid barometer, a Brunton compass, a Maignen filter, one or two prospecting-picks, medicine cases, note-books, and pencils. Exploratory parties were also supplied with camp- and cooking-equipment.

Geology.

The coal-deposits in the Mixteca region must have been known for more than half a century. There is an old drawing, bearing the title, *Croquis de la Area Carbonifera de Tlaxiaco descurbierta por Jose Vincente Comacho en 1850.* (Sketch of the Tlaxiaco Carboniferous Area discovered by Jose Vincente Comacho in 1850), upon which are shown several drifts and outcrops; but no work, except a few short drifts scattered over a large area, and a trench near Mina Consuelo, had been done in the region prior to 1907.

The first geological study of the Mixteca region, of which records can be found, was made by Inginiero Santiago Ramirez, who examined, in 1881, some coal-outcrops near the boundary

between Oaxaca and Puebla. In the same decade, Messrs. Felix and Linke made geological studies in the vicinity of Tlaxiaco; and in 1887–1888 Sr. Jose G. Aguilera, now Director of the Instituto Geologico Nacionale, examined the vicinity of Tezoatlan and the northern part of the State of Oaxaca. The activity of the Oaxaca Iron & Coal Co. attracted to this undeveloped field the interest of the National Geological Institute, which, in the fall of 1908, sent an engineer to visit the Mixteca region. He collected for the Institute considerable geological data and numerous fossils, and examined some coal-outcrops, which, however, he regarded as possessing no importance, since he was able to find but few samples that carried less than 18 per cent. of ash, which he considered to be a maximum for useful coal. In the spring of 1909, the Director himself accompanied me in a brief tour of inspection to some of the deposits; and somewhat later commissioned another party, composed of Prof. G. R. Wieland and Inginiero Bonilla, to visit the Mixteca region. They spent several months in the field; but the work of these geological parties was directed rather to the correlation of the various strata, to petrographical determinations, and to the collection of fossils, than to economic geology.

Geology of Western Oaxaca.

In the territory under discussion the general geology may be described as follows:

The lowest formation is the Archaic, consisting of gneiss, mica-schists, and mica-slates. On this are superposed small areas of Jura-Trias, while over larger areas appears the Cretaceous formation. The pre-Cretaceous Mesozoic rocks generally consist of shales (varying greatly in composition), coarse and fine sandstones, and conglomerates, also some quartzites. The Cretaceous is represented mostly by massive limestone, although in some parts slates and calcareous sandstones are found. Above the Mesozoic formations occur in some places the Tertiary red sandstones and conglomerates, and in other places "*caliche*," which is either of Tertiary or Quartenary age.

Throughout these various formations, although more predominant near the junction of the Archaic and the upper sedimentary rocks, large areas are covered by Tertiary intrusives

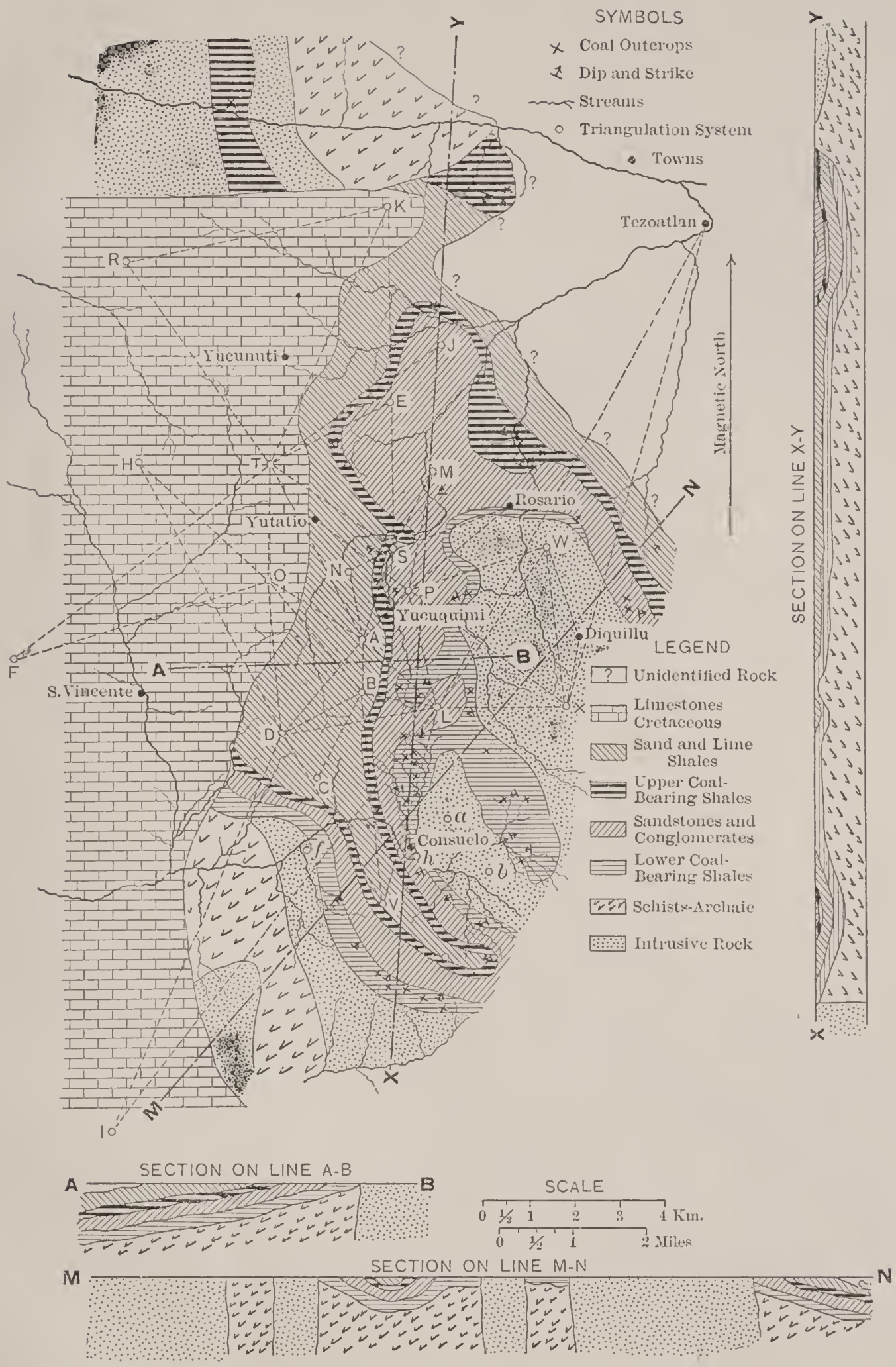
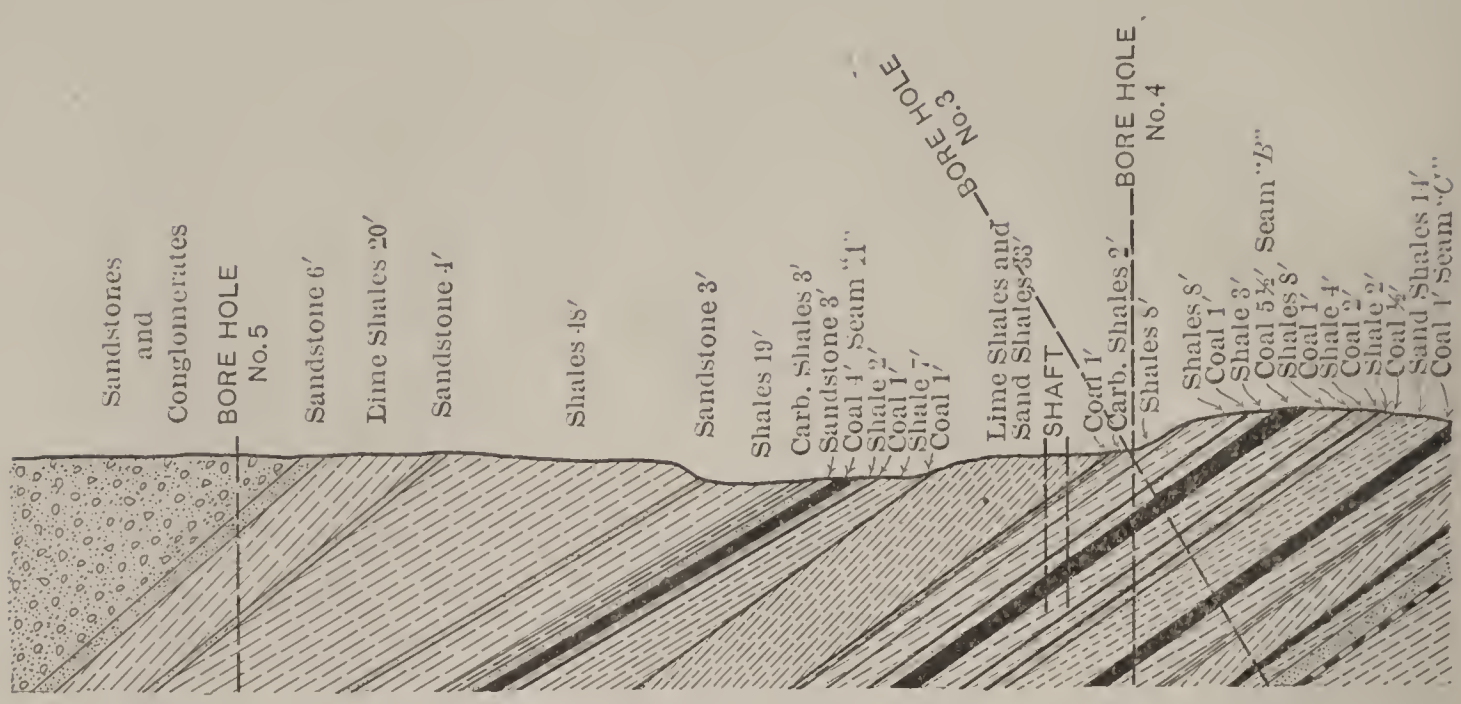
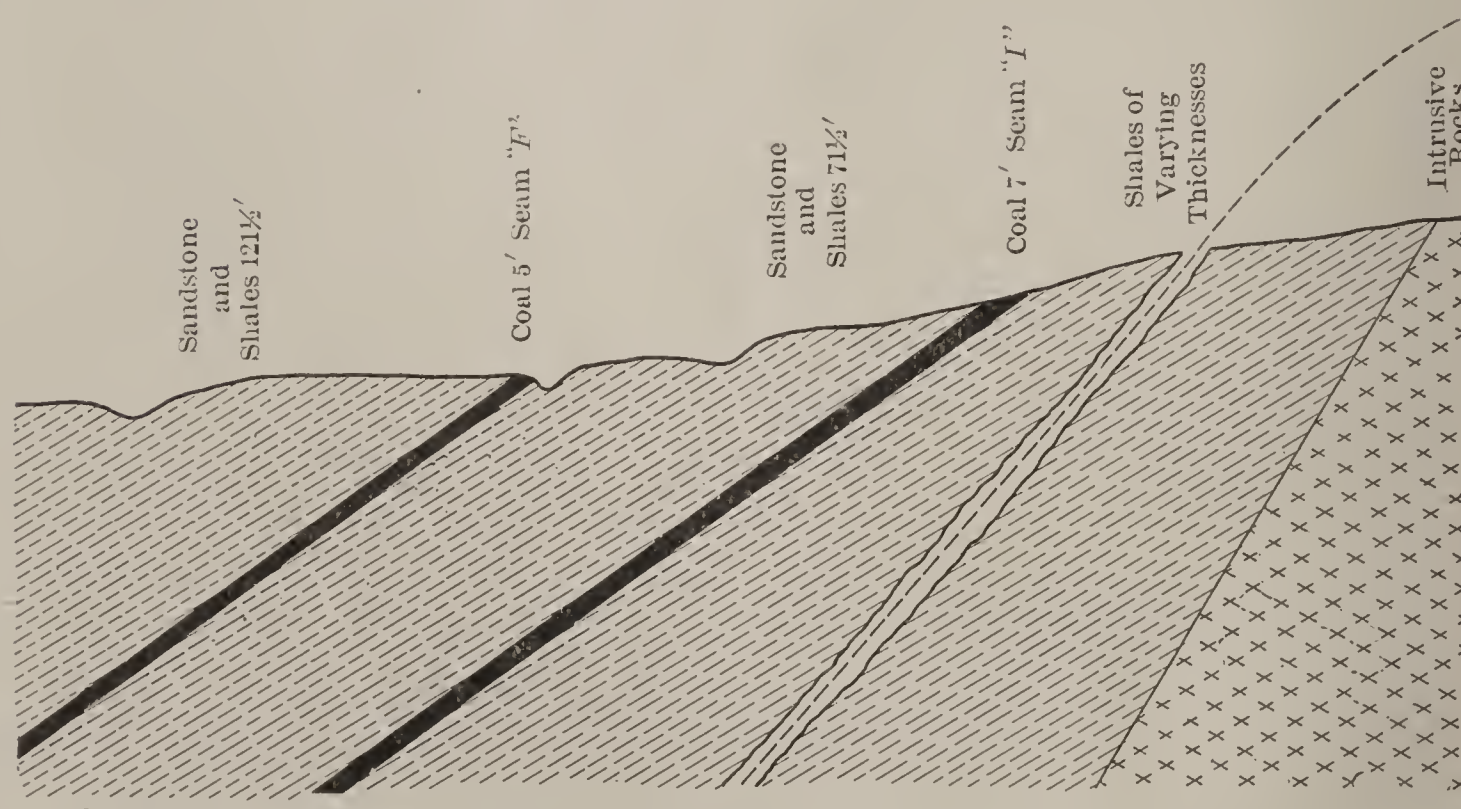


FIG. 2.—GEOLOGICAL MAP AND SECTIONS, VICINITY OF MINA CONSUELO, OAXACA, MEXICO.



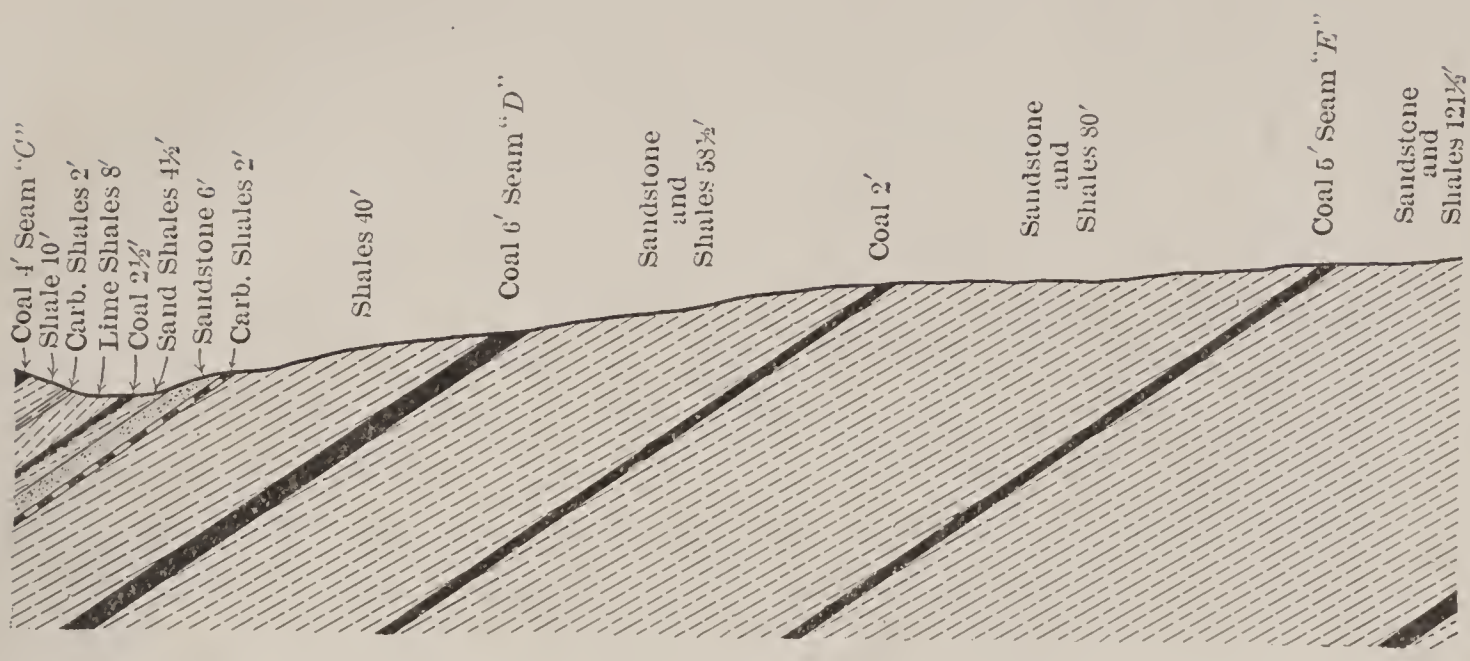
A

(andesites, basalts, rhyolites, etc.), while in some localities lava-flows and masses of obsidian are found. The Mesozoic formations of the region are extremely interesting to palæontologists, on account of the large number of fossils which they contain. The Jura-Triassic carries a great variety of mollusca and plant-



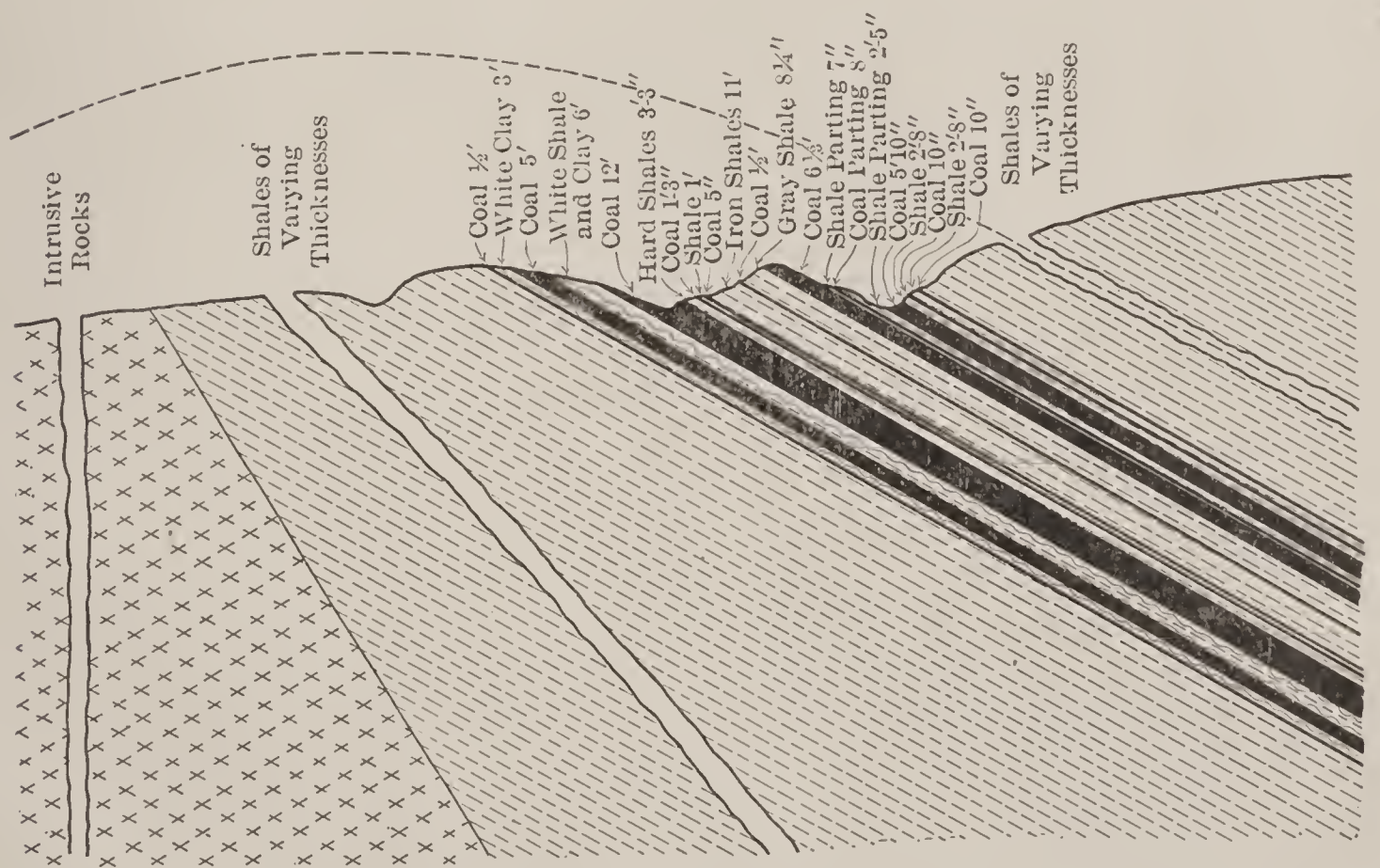
C

FIG. 3 (A, B, C, D).—GEOLOGICAL SECTION, VICINITY OF MINA CONSUELO, BORE-HOLES



B

forms. The mollusca include several forms of *trigonia* and *stefonigero;* while among the plant-forms cycads are predominant, although there is beyond doubt a great variety of other forms. Professor Wieland, in his paper entitled The Williamsonias of the Mixteca Alta, says: "I am of the opinion that



D

Oaxaca, Mexico, at Right Angles to the Strike-Line and through Nos. 3 and 4.

the Mixteca Alta is one of the most promising and accessible regions for the student of fossil plants yet discovered."[3]

The various formations of the pre-Cretaceous Mesozoic have not been correlated, being grouped under a general term as Jura-Trias; but the thick Cretaceous limestone is sufficient as a geological horizon for field purposes; and an intermediate horizon has been used, consisting of layers of black oyster-shells, and called by the members of the corps "the black shell-rock."

The Tezoatlan coal-field has been more closely examined than any of the others, and the following section of it may be regarded as typical:

Downward Section of Tezoatlan Coal-Field.

Cretaceous limestones,	massive and of great thickness.
Calcareous and arenaceous shales, including the "black shell-rock,"	about 500 ft.
Upper coal-bearing shale,	110 ft.
Sandstones and conglomerates,	800 ft.
Lower coal-bearing shales,	at least 800 ft.
Intrusive or archaic rocks.	

The upper coal-bearing shales have not been examined, except superficially, since the lower shales appeared to have greater value. Several sections have been made of various portions of the lower coal-bearing shales, which vary in thickness according to where they are cut off by the intrusive rock. The following is offered as representative:

Section below the 800 *Feet of Sandstones and Conglomerates Noted in Preceding Section.*

	Ft.	In.
Sandstones,	6	0
Calcareous shale,	20	0
Sandstones,	4	0
Ferruginous, calcareous, and arenaceous shales,	48	0
Sandstone,	3	0
Ferruginous and arenaceous shales,	19	0
Carboniferous shales,	3	0
Sandstone,	3	0
Coal. Seam A,	4	0
Shale parting,	2	0
Coal,	1	0
Blue shale,	7	0
Coal,	1	0

[3] *The Botanical Gazette*, vol. xlviii., No. 6, p. 427, et seq.

	Ft.	In.
Arenaceous and calcareous shales,	33	0
Coal,	1	0
Carboniferous shales,	2	0
Blue shales.	8	0
Arenaceous shales,	8	0
Coal,	1	0
Shale,	3	0
Coal. Seam B,	5	6
Shale,	8	0
Coal,	1	0
Shale,	4	0
Coal. Seam C,	2	0
Shale parting,	2	0
Coal,	0	6
Arenaceous shales,	14	0
Coal,	4	0
Shale,	10	0
Coal,	2	0
Calcareous shales,	8	0
Coal,	2	6
Arenaceous shales,	4	6
Sandstones,	6	0
Carboniferous shales,	2	0
Shales,	40	0
Coal. Seam D,	6	0
Sandstones and shales,	58	6
Coal,	2	0
Sandstones and shales,	80	0
Coal. Seam E,	5	0
Sandstones and shales,	121	6
Coal. Seam F,	5	0
Sandstones and shales,	71	6
Coal. Seam I,	7	0
Sandstones and shales,	?	
Coal,	0	10
Shale,	2	8
Coal,	0	10
Shale,	2	8
Upper split of coal seam No. 3,	5	10
Shale parting,	2	5
Coal parting,	0	8
Shale parting,	0	7
Lower split of coal-seam No. 3,	6	4
Gray shale,	8	3
Coal,	0	6
Iron shales,	11	0
Coal,	0	5
Shale,	1	0
Coal,	1	3
Hard shales,	3	3
Coal. Seam 2,	12	0
White shale and clay,	6	0

	Ft.	In.
Coal. Seam 1, ...	5	0
White clay, ...	3	0
Coal, ...	0	6
White and iron-shales of varying thickness down to intrusive rock.		

This section shows a total of 83 ft. 2 in. of coal, in which 15 seams over 2 ft. in thickness aggregate 72 ft. 8 in., and 9 of these, exceeding 3 ft., give an aggregate thickness of 64 ft. 8 in.

The intrusive rocks cut these formations at various points, but, in the coal-fields proper, the nearest they come to the coal-seams is (excepting one or two places) about 100 ft. below coal-seam *K*. Coal-seam *K* is not designated in the section. On account of the undetermined rocks below seam *K* and above seam 3, the nomenclature of the seams was changed at this point.

The formations are faulted and folded, but not so much as would be expected. The dip is generally between 30° and 50° west at Mina Consuelo, and the same amount to the east at the opposite side of the basin. In places, the coal lies horizontal in small areas, while the faults, with the exception of quite a large one on practically the axis of the synclinal (where there has been a displacement of nearly 1,000 ft.), are unusually small, although numerous. Three faults have been found, of 200, 120, and 55 ft. displacement, respectively, while there are many others which vary from a few tenths of an inch to a foot or more. The general strike in the vicinity of Consuelo is N.-S., but in approaching the town of San Juan Diquillu it swings around to E.-W.

Coal-Fields and Character of Coal.

The field-headquarters were located in Tlaxiaco, which, although more than 80 miles by horse-trail from the nearest railroad-station, has a population of 8,000, a small water-supply, electric light, and a large number of stores. The relative locations of the various fields will be referred to this place.

In the Penasco field, 10 miles SE. of Tlaxiaco, a high-grade coal in small deposits was found by an exploring-party. A sample from the Junuzma mine gave, upon analysis, moisture, 9.45; volatile matter, 25.85; fixed carbon, 60.45; and ash, 4.25 per cent.

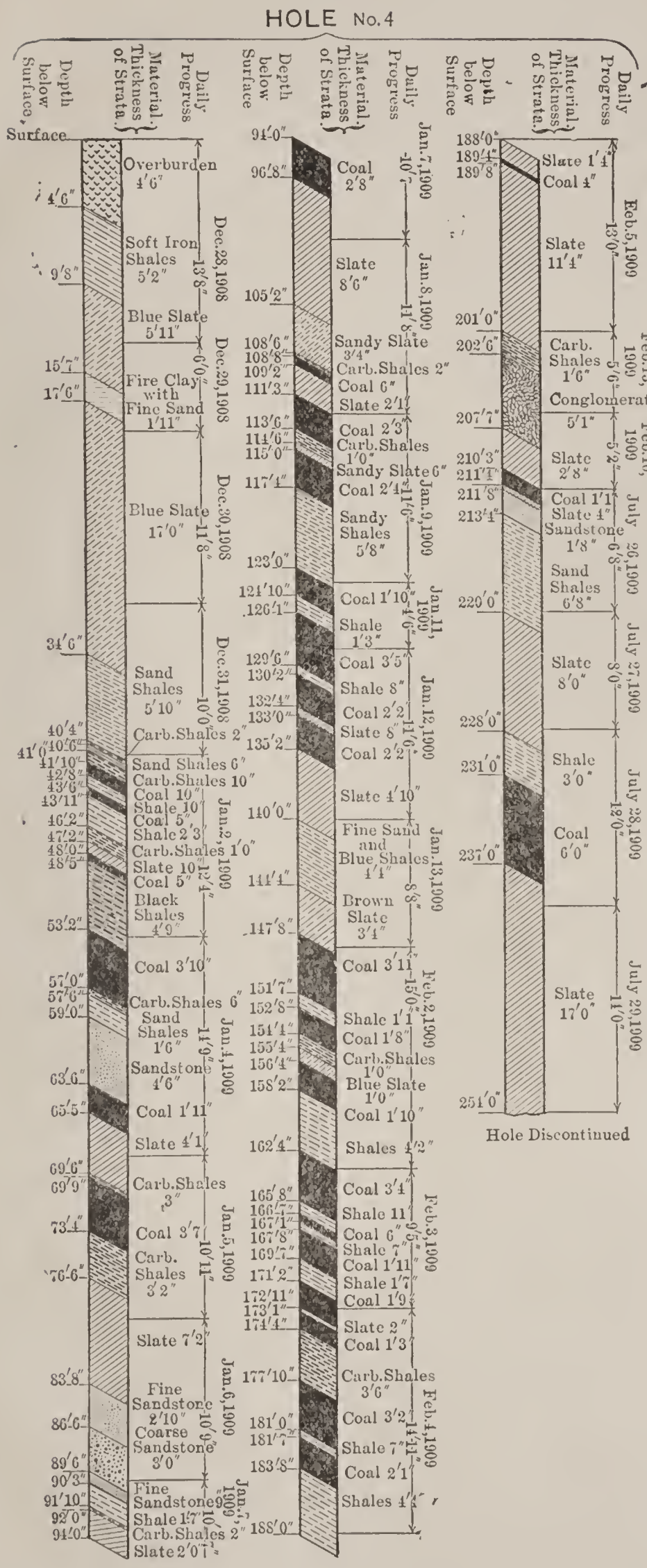


FIG. 4.—RECORD OF DIAMOND-DRILLING AT MINA CONSUELO, OAXACA, MEXICO.

FIG. 5.—SECTION OF SHAFT A ON AN EAST AND WEST LINE, MINA CONSUELO, OAXACA, MEXICO.

The Tepejilla field, about 20 miles NW. of Tlaxiaco, covers a small area; and the coal found there is high in ash and apparently small in quantity.

The Juxtlahuaca field includes outcrops in the vicinity of the towns of Juxtlahuaca and Silacayoapam, where preliminary investigation showed the coal to be non-coking and high in ash. Samples showed on analysis the following results:

	Juxtlahuaca. Per Cent.	Silacayoapam. Per Cent.
Moisture,	5.9	9.27
Volatile matter,		27.36
Fixed carbon,	42.0	39.93
Ash,	52.1	23.44
	Analyzed by O. I. & C. Co.	Instituto Geologico.

The Tecomatlan field, embracing the outcrops in the vicinity of Tecomatlan, in the State of Puebla, and Santa Ana Rayon, Oaxaca, is 75 miles NW. of Tlaxiaco. The coal here is soft and pulverulent and showed on analysis:

	Per Cent.	Per Cent.
Moisture,	1.8	2.0
Volatile matter,	17.1	18.3
Fixed carbon,	57.1	48.7
Ash,	24.0	31.0

The Tlaxiaco field, the Mixtepec field, 12 miles W. of Tlaxiaco, and the Tezoatlan field, 25 to 30 miles NW. of Tlaxiaco, are those in which most development-work has been done, and will be described in detail under separate headings.

In addition to the above localities, coal is reported as occurring in four or five other places; but samples showed it to be of inferior quality.

Tlaxiaco Field.

Since the company first acquired control of this field, its work was started here, and was greatly facilitated by the progressiveness of the people of Tlaxiaco, who, following the example of Sr. Salvador Bolanos Cacho, the *Jefe Politico* of the district, not only secured samples of iron-ore and coal from distant points, but aided us with their advice and in every possible way made our work pleasant and comfortable. I take this opportunity of expressing my appreciation of the uniform courtesy and kindness shown us by every one within

the boundaries of the State, from the Governor, Sr. Emilio Pimentel, down to the Presidente of the smallest town.

The Tlaxiaco field was sub-divided into three tracts, the Villaverde, the Stein, and the Rio Tlaxiaco. The work done upon the Villaverde and Stein tracts consisted in mapping and uncovering some 14 outcrops and securing samples, which show the coal to vary greatly in composition, much of it appearing to be too poor for commercial use. Analysis from one of these coals gave the following results:

	Per Cent.
Moisture,	2.07
Volatile matter,	16.77
Fixed carbon,	52.69
Ash,	28.47

The work on the Rio Tlaxiaco tract consisted of eight drifts, which had a total length of 900 ft., including cross-cuts, and exposed seams varying from 10 in. to 6 ft. 0 in. in thickness. Most of these seams are very dirty and show the effects of considerable faulting, the seams consisting of flakes of coal and slate. The following are the analyses of some of the better seams:

Seam Number	Thickness of Seam. Feet.	Moisture. Per Cent.	Volatile Matter. Per Cent.	Fixed Carbon. Per Cent.	Ash. Per Cent.
4	2	1.8	18.1	42.1	38.0
4–A	3	0.7	15.1	46.0	38.2
5	4	6.6	19.2	29.7	44.5
6	6	1.6	16.4	53.0	29.0

Mixtepec Field.

Upon the discovery of better coal at Mixtepec, the work was transferred to this locality and a large number of drifts were driven, the longest being over 1,100 ft., which showed that the seam was 25 ft. thick and extended over a large area. Numerous samples were taken, an average of the seam showing:

	Per Cent.
Moisture,	1.3
Volatile matter,	16.2
Fixed carbon,	67.5
Ash,	13.0

Besides this seam, known as the Esperanza, there are three others, designated as Fabrica, Soledad, and Southern. The Fabrica seam, 6 ft. thick, gave:

	Per Cent.
Moisture,	1.24
Volatile matter,	16.21
Fixed carbon,	60.23
Ash,	22.32

The Soledad seam, 5 ft. thick, showed:

	Per Cent.
Moisture,	1.06
Volatile matter,	14.03
Fixed carbon,	66.69
Ash,	16.22

The Southern seam, 3 ft. thick, gave:

	Per Cent.
Moisture,	13.69
Volatile matter,	28.78
Fixed carbon,	25.38
Ash,	32.15

The Southern seam, which appears to be rather a lignite than a true coal, is located about 4 miles from the Mixtepec field proper.

All of the above analyses represent the "run-of-mine," the large pieces of slate only being removed. As the Mixtepec coal is quite soft, some crude tests showed that the ash could be reduced to one-half the original content by sizing on revolving screens, while washing or jigging would make a still greater reduction.

As the percentages of ash appeared high, two samples were taken and tested in a calorimeter to determine their fuel-value. The dirty coal, carrying 29.38 per cent. of ash, yielded 11,400 B.t.u., while a clean picked sample, containing 3.85 per cent. of ash, gave 15,900 B.t.u.

As the evidence of the value of the coal-fields appeared to increase greatly upon examination, it was decided to purchase a diamond-drill; and, the nearest point to the railroad being the Tezoatlan field, the drill was sent there. Later a second drill was erected at the same place, and the entire force was moved to Mina Consuelo.

Tezoatlan Field.

For the past 18 months all the development-work of the company has been confined to the Tezoatlan field, and here the work has reached its highest development, although still in progress. Some 35 drifts have been driven into the coal in order to show the continuity of the coal-seams along the outcrop, while seven diamond-drill holes and a shaft have been sunk to determine its extent in depth. More than 71 sq. miles have been covered by a geological survey; and the data thus collected have been mapped, while detailed geological and topographical surveys have been completed on 350 acres, and are now in progress on 1,000 additional acres.

As shown in the geological section, the coal-seams 3 ft. or more thick in this locality have a total true thickness of 64 ft. 2 in., although in part of the field the intrusive rocks have cut out the lower 29 ft. 2 in. of the seams, leaving available 35 ft. of coal. As the average dip is 30° or more, these true thicknesses will be equivalent to vertical thicknesses of 74 and 42 ft., respectively, and would yield, according to the rule of thumb (that 1 ft. vertical thickness gives a yield of 1,200 tons of coal per acre), 88,800 and 50,400 tons per acre, respectively. The upper 35 ft. of coal has been traced over an area of 3,000 acres, while the total thickness of 64 ft. has been traced for a distance of 1.25 miles, though the work has not yet reached a stage permitting the determination of the area underlain by the total thickness of seams. The coal may be called an anthracite, being hard and dense and burning without smoke, a typical analysis showing:

	Per Cent.
Moisture,	1.0
Volatile matter,	5.5
Fixed carbon,	73.5
Ash,	20.0
Sulphur,	0.06

11,500 B.t.u.

This analysis represents the coal when mined and picked; the "run-of-mine," unpicked, carrying about 25 per cent. of ash.

The Tezoatlan coal-field is a large basin, extending in a general N-S. direction, the distance between the eastern and west-

ern outcrops being, near the southern end, about 2 miles, while, on the north, the western outcrop is hidden by the Cretaceous limestones, which are unconformable to the lower strata.

An interesting feature of this coal-field is, that the intrusive rocks, which are considered to be Tertiary, have had practically no effect on the coals. In some places, coal-seams are found occurring with surprising uniformity within 20 ft. of the intrusive rocks. The formations of the various strata in this vicinity are extremely interesting; and the rapid alteration of the strata (consisting of coal, shale, fine and coarse sandstones) shows that there was a constant variation of the depth of water during deposition.

Iron-Ore.

Although the preliminary reconnoissance in 1906 had for its object the investigation of certain deposits of iron-ore, with the idea of utilizing them in the manufacture of iron, using either charcoal or imported coke as fuel, the coal-deposits appeared to be of more immediate value than those of iron-ore; and therefore nearly all the work has been done on the fuel-deposits.

There is no doubt that a waiting market exists for iron- and steel-products in Mexico, as these now command high prices on account of freight charges and import duties. Pig-iron sells for $40 per ton in Mexico City, castings at $50 per ton and upward; and the duty on pig-iron is $5 per ton, while that on certain finished products is as high as $150 per ton.

The iron-ores in the State of Oaxaca are of high grade. Thirty-three samples, taken from within an area of 4 sq. miles and tested in the field-laboratory, showed an average of 60.87 per cent. of metallic iron. George C. Davis, chemist, of Philadelphia, made an analysis of a sample, closely representing the average of the Cahuacua ore, which showed Fe, 65.86; S, 0.06; and P, 0.03 per cent. The phosphorus and sulphur are low in all the iron-ores of this district, and in the deposit which has been most largely developed there are indications of large quantities of high-grade Bessemer ore. Samples from a deposit at El Carnero averaged 66 per cent. of metallic iron, and Mr. Davis made an analysis of a hand-sample, with the result: Fe, 63.20; SiO_2, 8.25; P, 0.024; and S, 0.03 per cent. In the locality known as La Ferreria, the average iron-content of the ore,

as determined in the company's laboratory, was 66.02 per cent.; and an analysis by Mr. Davis from a different sample showed Fe, 68.93; SiO_2, 2.80; P, 0.026 per cent. In the vicinity of Tlaxiaco iron-ores were found containing Fe, 51.71; SiO_2, 4.61; P, 0.026 per cent. Some iron-ore deposits examined in the State of Puebla gave Fe, from 42.40 to 67.0; SiO_2, from 1.30 to 15; CaO, from a trace to 8.80; P, from 0.004 to 0.051, and S, from 0.01 to 0.15 per cent.

These analyses are offered to show that ores collected from deposits scattered over a large area are rich in iron and low in sulphur and phosphorus. A few months' work at the Cahuacua deposit disclosed about 4,000,000 tons of iron-ore. The El Carnero ore is mainly magnetite; that of Cahuacua, mixed magnetite and hematite; that of La Ferreria, hematite and limonite; and that near Tlaxiaco, limonite. In the State of Puebla, the iron-ores are limonite and magnetite.

Transportation.

The extent of the exploratory work herein described was deemed essential by reason of the location of the coal-deposits as related to existing transportation-facilities. The railroads of Mexico, which now aggregate 14,000 miles, have in but few instances penetrated the mountainous section, and no existing line is nearer than 80 miles to the coal-fields. But, coal and iron-ores having been found in sufficient quantity to warrant the construction of railroad communications, reconnoissances of several railroad-routes have been made, which need not be discussed at this time. Notwithstanding the mountainous country traversed, practical routes were found, which would connect the present railway-system of Mexico with the coal- and iron-ore deposits of Oaxaca, and might be extended to the Pacific coast, with moderate curves and grades not exceeding 2 per cent.; the estimated construction-cost being moderate for the character of the territory traversed.